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Agronomic and Economic Performance of Soybean as an Entry Crop to an Organic Cropping System following Conventional Corn, Spring Barley, or Soybean

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Introduction

Consumer demand for organically produced field crops has increased in the U.S., so organic flour and tofu are readily available in most grocery stores (USDA, ERS, 2015a). Organic grains and soybeans have substantial price premiums over conventionally-produced crops, providing market incentives for growers (USDA, ERS, 2015a). Recent downward trends in grain crop and soybean prices have prompted more field crop producers in New York, who frequently practice a corn-soybean-wheat/red clover rotation, to contemplate transitioning from conventional to an organic cropping system. The USDA, however, requires a 36-month transition period that prohibits the use of GMO crops, synthetic fertilizer, pesticides, etc. before the land can be certified as organic and eligible for the organic price premium (USDA, 2012). Furthermore, a recent USDA publication (USDA, 2015b) indicated that organic compared with conventional field crop production had lower yields and higher per-acre total economic costs, despite higher profits for organic production. Consequently, field crop producers must grow corn, soybean, or wheat with organic practices during the transition period, which could result in potentially higher production costs and potentially lower yields, with no price premium. Identification of the best entry crop during the transition period to an organic cropping system is thus critical for maintaining profitability, especially given the relatively low cash receipts received by corn, soybean and wheat growers in 2015 (USDA, ERS, 2016a).

Numerous studies comparing organic and conventional cropping systems have been conducted in the Upper Midwest U.S. In a cropping system study established in 1989 near Lamberton MN, organic corn in a corn-soybean-oats/alfalfa-alfalfa rotation yielded similarly as conventional corn in a corn-soybean rotation from 1993-2009 (Porter et al., 2003; Coulter et al. 2011). Organic soybean, however yielded only 75% of conventional soybean in their respective rotations over the same period. Organic corn, despite higher machinery costs, had $35/acre lower production costs compared with conventional corn because of lower seed costs as well as no herbicide costs (Delbridge et al., 2010). Likewise, organic soybean had $41/acre lower production costs compared with conventional soybean, primarily because of lower weed control costs (Delbridge et al., 2010). When factoring in the organic price premium (2.17 price ratio for corn and 2.27 for soybean), the 4-year organic rotation had $527 net revenue compared with $295 for the 2-year conventional rotation (Delbridge et al., 2010).

Machinery ownership costs, however, were not included in the first analyses of this study. When comparing the 4-year organic rotation with the 2-year conventional rotation, machinery ownership costs averaged $59/acre across organic farm sizes of 320, 560 and 800 acres compared with $74/acre across conventional farm sizes of 560, 1120, and 1560 acres (Delbridge et al., 2011). The organic rotation had net returns of $114,000 compared with conventional net returns of $72,000 for a 560 acre farm (Delbridge et al., 2011). The organic rotation also had net returns of $296,000 for the largest farm size (800 acres), compared with conventional net returns of $220,000 for its largest farm size (1560 acres), despite the farm-scale advantage of conventional production.

In another Minnesota cropping system study established in 2002 near Morris MN, organic compared with conventional corn yielded 34% lower, whereas organic compared with conventional soybean yielded statistically similar (but 15% numerically lower) during the transition period when comparing 2-year conventional and organic corn-soybean rotations (Archer et al., 2007). Organic corn yielded 34% lower mostly due to lack of available soil N, associated with low N content of the solid dairy manure applied to organic corn. The 2-year organic compared with the 2-year conventional rotation had $52/acre higher production costs, despite $172/acre lower seed, fertilizer and pesticide costs, because of higher labor, diesel, manure hauling, and machinery ownership costs. Consequently, the conventional 2-year rotation had $207/acre higher net present value when compared with the 2-year organic rotation during the transition period in the absence of an organic premium (Archer et al., 2007).

In this same MN study, the entry crop into an organic cropping system had a major impact on risks and returns during the transition phase (Archer and Kludze, 2006). Based on yield data and inputs from the same study, soybean as the entry crop provided a $283 advantage of net present value of net returns compared with corn in the corn-soybean organic rotation. In the 4-year organic rotation, wheat as the entry crop provided a $229 advantage over other entry crops (Archer et al., 2007). Nevertheless, a simple dynamic adoption model indicated that transitioning to an organic cropping system as rapidly as possible, regardless of the entry crop, would result in the highest expected long-term profit (Archer and Kludze, 2006).

In a cropping system study established in 1990 at Arlington and Elkhorn, WI, a no-till (NT) conventional corn-soybean rotation compared with an organic corn-soybean-wheat rotation averaged $130 and $149 higher economic mean returns, respectively, in the absence of organic premiums (Chavas et al., 2009). In the presence of government payments and organic premiums, the organic corn-soybean-wheat rotation had $210 and $165 higher economic mean returns, respectively, compared with the conventional NT corn-soybean rotation (Chavas et al., 2009). The conventional NT corn-soybean rotation yield trend, however, averaged 2.4 bushels/acre compared with 1.6 bushels/acre for the organic corn-soybean-wheat rotation from 2009 to 2012 (Baldock et al., 2014), perhaps because of technology advances in the conventional cropping system and/or increased weed competition in the organic cropping system.

In a cropping system study established in 1996 at the USDA-ARS Beltsville, MD Agricultural Research Center, organic corn in a corn-soybean-wheat/vetch rotation yielded 28% lower compared with conventional NT corn in a corn-soybean-wheat/soybean rotation during the transition years from 1996 to 1998 (Cavigelli et al., 2008). After the transition period, organic compared with conventional corn yielded 40% lower in their respective 3-crop rotations (Cavigelli et al., 2008). The lower organic corn yields were associated mostly with low soil N availability (73%) and weed competition (23%). After the transition period, organic soybean compared with NT conventional soybean yielded 24% lower in their respective 3-crop rotations (Cavigelli et al., 2008). Lower organic soybean yields were mostly associated with greater weed competition. In the 3-year period (2000-2002) following the transition, the organic compared with the conventional cropping system, despite lower corn and soybean yields, had net returns $208/acre higher (Cavigelli et al., 2008). Economic risk in the 3-year organic system, however, was 3.9 times greater compared with a 6-year organic rotation (corn/rye-soybean-wheat-alfalfa-alfalfa-alfalfa).

In a cropping system study, established in 1999 at Greenfield, IA, corn and soybean in an organic corn-soybean-oat/alfalfa-alfalfa rotation compared with a conventional corn-soybean rotation yielded similarly during the transition period (Delate and Cambardella, 2004), resulting in higher profitability for the organic cropping system because of lower production costs (Delate et al., 2003). In the second phase of the study, corn and soybean again yielded similarly between cropping systems so the organic cropping system was far more profitable because of lower production costs in corn and higher prices received for organic corn and soybeans (Delate at al., 2014).

In a cropping system study, established in 2005 near Aurora NY at a Cornell Research Farm, organic corn yielded 65% of County (Cayuga) yields and organic soybean yielded 91% of County yields during the transition phase (Caldwell et al., 2014). After the transition phase, organic corn yielded 98 to 114% compared with County yields; whereas organic soybean continued to yield ~90% of County yields (Caldwell et al., 2014). Soybean was the best entry crop in this study with a negative relative net return of $67/acre compared with a negative relative net return of ~$700/acre for organic corn. After the transition period, relative net returns were mostly positive for both corn and soybean (Caldwell et al., 2014).

Long-term cropping systems experiments, though beneficial, are somewhat limited in the analyses of conventional vs. organic cropping systems because management practices are fixed and maybe not available to organic producers and the "human" management factor of organic production is missing (McBride and Greene 2009). Using data from the Agricultural Resource Management Survey in 2006 (1425 conventional and 237 organic producers), McBride and Greene (2009) reported that organic soybean yielded 34% lower compared with conventional soybean. Furthermore, organic soybean producers had higher operating costs ($103) and higher operating and capital ownership costs ($194) compared with conventional producers ($92 and $160, respectively). Consequently, organic soybean producers had higher average operating costs/bushel compared with conventional producers ($3.32/bushel vs. $1.95/bushel, respectively). Likewise, organic producers had much higher total economic costs/bushel compared with conventional soybean producers ($10.97 vs. $5.87/bushel, respectively). Nevertheless, organic soybean producers had greater returns compared with conventional producers because of the organic price premium (2.67 ratio). The survey data indicate that the organic price premium is crucial for profitability in organic soybean production because of lower yields and higher production costs.

A major impediment to adoption of organic field crop production for conventional producers is the uncertainty associated with selection of the best entry crop and uncertainty of what management practices to adopt on the selected entry crop (Archer et al., 2006). Three of the myriad objectives of this study are: 1) to identify the best previous conventional crop (2014) for the transition to an organic cropping system, 2) to identify the best entry crop to plant during the first transition year (2015), and 3) to evaluate recommended and high input management (high seeding rates and organic seed treatment, etc.) to determine if high input management increases weed competitiveness and agronomic performance of the entry crop.

Materials and Methods

We initiated a 3-year cropping system study in 2015 in contiguous fields with either corn, soybean, or spring barley as preceding conventional crops (2014) at a Cornell Research Farm near Aurora, NY. All three fields (tile-drained Honeoye silt loam soils) were mold-plowed on May 22 followed by secondary tillage (cultimulching) the following day. We selected two treatments (recommended and high input) on corn and soybean in the conventional and organic cropping systems. We used composted chicken manure, a 5-4-3- analysis, as a starter fertilizer and as the N source in organic corn. We estimated that about 50% of the N from the composted chicken manure would be mineralized and available to organic corn in 2015. The experimental design was a split-split-plot with four replications with the previous crop as the whole plot (125 by 720 feet), cropping system as the sub-plot (125 by 180 feet), and management inputs as the sub-sub plot (125 feet by 10 feet).

Table 1 provides a description of management inputs in all four corn treatments. Major differences between conventional and organic corn include

a) a treated (insecticide/fungicide seed treatment) GMO corn hybrid, P9675AMXT with the AMXT, LL and RR2 traits, vs. the non-GMO isoline, P9675 (no seed treatment in recommended input but an organic seed treatment, Sabrex, mixed in the seed hopper in the high input treatment), b) 250 lbs./acre of 10-20-20 vs. 325 lbs./acre of composted manure as starter fertilizer, c) side-dressing (June 26 at the 5^{th} leaf or V5 stage) 80 to 160 lbs. actual N/acre (depending on previous crop and management treatment) with liquid N as the source (30-0-0) vs. the same actual N rates of composted chicken manure applied pre-plant on May 23, and 4) Roundup (Glystar Plus) at 40 oz./acre for weed control at the V5-6 stage (June 27) vs. tine weeding to control weeds in the row at the V2 stage (June 12), followed by close cultivation to the row at the V4 stage (June 20), and cultivations between the rows at the V6 stage (June 25) and again at the V9 stage (July 6), respectively. Seeding rates of 29,600 kernels/acre were used in recommended input and 35,500 in high input treatments of both cropping systems (Table 1).

Table 2 provides a description of management inputs in all four soybean treatments. Major differences between conventional and organic soybean include a) treated (insecticide/fungicide seed treatment) GMO variety, P22T41R2 with the RR2Y and SCN traits vs. a non-GMO variety, 92Y21 (organic seed treatment mixed in the seed hopper of the high input treatment), b) 15 inch vs. 30-inch row spacing (for cultivation of weeds), and c) Roundup (Glystar Plus) at 40 oz./acre for weed control (June 27) vs. tine weeding to control weeds in the row at the V2 stage (June 12) followed by close cultivation to the row (June 20) and cultivations between the rows on July 6 and July 16, respectively. Seeding rates of 150,000 and 200,000 seeds/acre were used for recommended and high input treatments in both cropping systems. Conventional soybean in the high input treatment also received the fungicide, Priaxor at 4 fl. oz. /acre at the beginning pod (R3) stage (July 31) for potential disease problems and overall plant health. We did not fertilize soybeans because conventional soybean growers typically do not use fertilizer, instead relying on starter fertilizer from the previous corn or small grain crop to provide the P and K, and N-fixing bacteria on soybean roots to provide N. We did not use a food-grade soybean variety in this study because the crop cannot be marketed as organic during the transition years.

We harvested soybean in all three fields on September 23 at ~11% moisture and no-tilled wheat into soybean stubble the following day. We decided to no-till wheat in both cropping systems because of the paucity of visible weeds, especially perennial weeds, in both cropping systems. We will not provide management inputs for conventional and organic wheat because wheat has not been harvested at the time of this writing.

The average soybean price received by farmers in NY in 2015 was $8.75 (USDA, 2016b). Production costs for the different management inputs in soybean for the two cropping systems are listed in Table 3. At the end of the 3-year study, we will identify the optimal crop sequence with the best management inputs during the transition period using marginal economic analyses. We estimated values of production, costs of production, and estimated returns only for soybean following three previous crops in conventional and organic cropping systems under recommended and high input management. Soybeans are assumed initially, based on agronomic data, to be the most beneficial entry crop. Analysis focused on enterprise budget items that differed among the treatments, namely the value of production associated with soybean yield differences as well as cost differences for inputs (Table 4). Returns to variable and fixed inputs that do not differ between conventional and organic soybean production under recommended and high input management were calculated. For this analysis, selected variable inputs include: seed, other inputs (Cell-Tech inoculant, Sabrex seed treatment, Glystar Plus herbicide, and Priaxor fungicide); labor and machinery operating inputs (repairs and maintenance, fuels and lubricants) for tasks excluding tillage, planting and harvesting tasks, except for hauling, where hauling cost ($0.10/bushel) is a function of yield (Lazarus, 2015). Cost of production values reported for fixed inputs exclude farm machinery ownership costs for tillage, planting and harvest, land charges, and values of management inputs.

Previous crop, cropping systems, and management inputs were considered fixed and replications random in the ANOVA model for agronomic analyses for the corn data and the agronomic and economic (estimated returns) analyses for soybean data using PROC MIXED (SAS, Inst., 1998). The Bartlett test (0.01) indicated that all variances were homogeneous for agronomic data in both crops and economic data in soybean. Least square means of the main effects (previous crop, cropping system, and management inputs) were computed and the Tukey-Kramer option of the LSMEANS statement was used to determine differences among least square means of the main effects at $\partial = 0.05$. Two-way interactions (previous crop by cropping system and/or cropping system by management inputs), however, were detected for most measured or calculated variables so the interaction comparisons will be presented. Differences among least square means for cropping system treatments within each previous crop were calculated using Fisher's protected LSD according to procedures for split-split plot experiments by Little and Hills (1975).

Results and Discussion

Corn yield showed a previous crop x cropping system interaction (magnitude differences across previous crops). Organic compared with conventional corn yielded 40% lower following the 2014 corn crop, 30% lower following soybean, and 20% lower following the small grain crop (Table 5). These results agree with findings from other cropping system studies that have reported lower organic corn yields during the transition period (Archer et al., 2007; Cavigelli et al., 2008; Caldwell et al., 2014). In Iowa, however, organic and conventional corn had similar yields during the transition period (Delate and Cambardella, 2004).

Lower organic compared with conventional corn yields were associated with a myriad of factors. Organic corn had lower emergence rates (perhaps due to no seed treatment and/or no BT rootworm gene), lower corn populations at the V10 stage (lower emergence rate and minor cultivation damage to the crop), especially in the recommended input treatment, and higher (6x) weed densities compared with conventional corn (Table 5). Lower plant densities (<25,000 plants/acre in the recommended inputs) and higher weed densities (>2.15 weeds/m^2 following small grain or soybean crops) probably contributed somewhat to the lower organic corn yields, as noted in the cropping system study at Beltsville, MD (Cavigelli et al., 2008). Nevertheless, N status of the organic corn crop was probably the most important factor, as indicated by visual symptoms of N deficiency throughout the grain filling period, later confirmed by lower stalk nitrate status and grain N content of organic corn, regardless of management inputs (Table 5). Other studies (Archer et al., 2007; Cavigelli et al., 2008) have also attributed a lack of available soil N for poor organic corn yields during the transition years. Based on this single year of data, corn should not be the first choice as the entry crop to an organic cropping system. Corn, however, could still prove to be the best entry crop during the 3-year transition period, depending upon the agronomic and economic performance of soybean (Year 2) and wheat (Year 3) in this rotation (Archer and Kludze, 2006).

As with corn, soybean yields showed a previous crop x cropping system interaction. Unlike corn yield, the interaction was directional with organic compared with conventional soybean yielding similarly following corn and soybean but yielding 17% lower when following a small grain crop (Table 6). The organic soybean yield data mostly agree with a MN study that showed that organic and conventional soybean yielded similarly (statistically, but numerically 15% lower, Archer et al., 2007). In two MN cropping systems studies, however, organic compared to conventional soybean had significantly lower yield trends after the 1st transition year, as evidenced by much lower organic soybean yields in Year 2 and 3 of the transition period (Mahoney et al., 2004; Archer et al, 2007).

Organic soybean yielded as well as conventional soybean because of excellent emergence rates, plant establishment rates, and satisfactory weed control. Organic compared with conventional soybean emerged 1 day earlier following all previous crops, had ~10% higher plant establishment rate in the recommended input treatment, and only moderately higher weed densities (< 1.0 weed/m^2) following all three previous crops in both management systems (Table 6).

Weed competition is typically the major variable that reduces organic soybean yield (Cavigelli et al., 2008; Coulter et al., 2011). Weed density at the full pod stage (R4) had a previous crop by cropping system interaction (directional) with no difference in weed densities among cropping system treatments following corn but greater weed densities in organic soybean following soybean and especially the small grain crop (Table 6). Conceivably, greater weed densities in organic soybean following a small grain crop contributed to the 17% lower organic yields. Nevertheless, the yield data from this study and another study at this site (Caldwell et al., 2014) indicate that soybean is an excellent entry crop to an organic cropping system. Furthermore, selecting soybean as the entry crop instead of selecting a rotation that delays soybean until Year 2 or 3 during the transition period may avoid reduced soybean yields because of increased weed competition (Mahoney et al., 2004; Archer et al, 2007). Cox et al. (1999), however, reported that soybean weed densities did not differ (but yields were 7% lower) when comparing soybean produced organically and conventionally over a 3-year period at this study site.

Organic compared with conventional soybean had similar selected production costs in recommended input but lower production costs in high input management (Table 4). Organic compared with conventional soybean had lower seed and other input costs (inoculant in conventional, organic seed treatment in organic high input, herbicide and fungicide in conventional high input), which offset higher remaining variable costs (labor, repairs and maintenance, fuels and lubricants, and interest on operating capital). In addition, organic compared with conventional soybean had higher fixed input costs (Table 4). Overall, organic compared with conventional soybean had virtually identical total selected production costs in recommended input and $45/acre lower costs in high input management. Other cropping system studies have reported lower total production costs for organic soybean (Delate and Cambardella, 2004; Delbridge et al., 2010; Delbridge et al., 2011) because of lower seed and pesticide costs. Archer et al. (2007), however, reported $52/acre higher organic compared with conventional soybean production costs because higher labor, diesel, and machinery ownership costs offset lower seed and pesticide costs. The 2006 survey of McBride and Greene (2009) also indicated that organic soybean producers had higher operating costs ($103) and higher operating and capital ownership costs ($194) compared with conventional producers ($92 and $160, respectively).

Revenue showed the same previous crop x cropping system interaction as yield because it is a function of yield (Table 7). Estimated returns also showed a previous crop by cropping system interaction, similar to yield (Table 7). Estimated returns did not differ between organic and conventional soybean when following corn. This agrees with previous results at this site (Cox et al., 1999), which showed similar estimated returns for soybean produced organically compared with conventional soybean production when following a corn crop. Organic compared with conventional soybean, however, had $66/acre lower estimated returns when following a small grain crop because of the yield advantage for conventional soybean. Organic soybean with recommended inputs also had $58/acre higher estimated returns compared with high input conventional soybean when following a soybean crop because of similar yield and lower production costs. Based on a single year of data, organic soybean with recommended inputs (no organic seed treatment to improve plant establishment or higher seeding rates to improve weed control) appears to be an excellent entry crop to an organic cropping system. Our economic data agree with other studies that indicate that soybean is the preferred entry crop (Archer et al., 2007; Caldwell et al. 2014). Another advantage of using soybean as an entry crop is that the grower does not need to use a food grade variety, which has a lower yield potential, in the first transition year. In comparison, wheat as the entry crop would result in soybean as the 3rd year crop in the rotation, the year that the crops could be eligible for the organic premium. Consequently, growers would probably plant a food grade variety with lower yield potential to capture the maximum organic premium.

Conclusion

Organic corn proved to be a poor agronomic choice as the entry crop to an organic cropping system because of somewhat poor emergence, plant establishment, weed control and plant N status. Soybean, on the other hand, proved to be a viable entry crop because of excellent emergence, plant establishment, and satisfactory weed control, resulting in mostly similar yields and estimated returns. Organic soybean under recommended compared with high inputs yielded similarly and had similar estimated returns indicating that organic soybean producers need not increase seeding rates (and use an organic seed treatment) for improved weed control as an entry crop at this site. The 2014 corn or soybean crops were the best previous crops for the soybean entry crop (probably because of excellent weed control during the last conventional year in 2014) to an organic soybean-wheat/red clover-corn rotation. Typically, soybean following soybean is not recommended, because of the potential for increased pest problems, and the lack of residual K, a major nutrient requirement of soybean, from the previous soybean crop. Consequently, soybean under recommended management inputs following conventional corn appears to be an excellent entry crop to an organic cropping system in New York because soybean can use residual K from the starter fertilizer in conventional corn, soybean is very competitive with weeds (Cox et al., 1999), which should be at low densities because of the arsenal of herbicides used on the previous conventional corn crop, and soybean fixes its own N so N fertilizer is not required. The overall performance of soybean as the entry crop, however, also depends upon the agronomic and economic performance of wheat (Year 2) and corn (Year 3) in a soybean-wheat/red clover-corn rotation (Archer et al., 2007). We will identify the optimal crop sequence and thus the most profitable entry crop at the end of the transition phase using marginal economic analyses.

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Table 1. Soil texture/drainage, planting date and rate, hybrid, tillage, starter and N fertilizer practices, and weed control practices for conventional and organic corn following three previous crops under two management treatments (recommended and high input) at a Cornell Research Farm near Aurora, NY in 2015.

	PREVIOUS CROP					
	CORN		SMALL GRAIN		SOYBEAN	
Descriptor	REC.	HIGH	REC.	HIGH	REC.	HIGH
	CONVENTIONAL CORN					
Soil texture/ drainage	Well- drained Honeoye silt loam					
Planting date	23-May					
Planting rate (kernels/acre)	29,600	35,500	29,600	35,500	29,600	35,500
Hybrid	P9675AMXT (insecticide seed treatment included in cost)					
Tillage	Moldboard plow/cultimulch					
Starter Fertilizer	10-20-20 (250 lbs./acre)					
Liquid N fertilizer (June 26)	120 lbs. N/ acre side-dress	180 lbs. N/acre side-dress	120 lbs. N/acre side-dress	180 lbs. N/acre side-dress	80 lbs. N/acre side-dress	120 lbs. N/acre side-dress
Herbicide application						

(June 27)	Roundup (Glystar Plus) 40 oz./acre					
	ORGANIC CORN					
Soil texture/ drainage	Well- drained Honeoye silt loam					
Planting date	23-May					
Planting rate (kernels/acre)	29,600	35,500	29,600	35,500	29,600	35,500
Hybrid	P9675 (no seed treatment)	P9675(organic seed treatment)	P9675(no seed treatment)	P9675(organic seed treatment)	P9675(no seed treatment)	P9675(organic seed treatment)
Tillage	Moldboard plow/cultimulch					
Starter Fertilizer	325 lbs/acre composted chicken manure (5-4-3)					
N fertilizer (pre-plant)	120 lbs. N/ acre composted chicken manure	180 lbs. N/ acre composted chicken manure	120 lbs. N/ acre composted chicken manure	180 lbs. N/ acre composted chicken manure	80 lbs. N/ acre composted chicken manure	120 lbs. N/ acre composted chicken manure
Tine weeding	June 12 (6 mph)					
Cultivate (3 times)	June 20, June 25, and July 6 (4 mph)					

Table 2. Soil texture/drainage, planting date and rate, row spacing, variety, tillage, weed control practices for conventional and organic soybean, and fungicide application on conventional soybean (high input) following three previous crops and two management treatments (recommended and high input) at a Cornell Research Farm near Aurora, NY in 2015.

	PREVIOUS CROP					
	CORN		SMALL GRAIN		SOYBEAN	
Descriptor	REC.	HIGH	REC.	HIGH	REC.	HIGH
	CONVENTIONAL SOYBEAN					
Soil texture/ drainage	Well- drained Honeoye silt loam					
Planting date	23-May					
Planting rate (seeds/acre)	150,000	200,000	150,000	200,000	150,000	200,000
Row Spacing	15-inch					
Variety	P22R41R2 (insecticide seed treatment included in cost)+ Cell-Tech inoculant					
Tillage	Moldboard plow/cultimulch					
Herbicide application (June 27)	Roundup (Glystar Plus) 40 oz./acre					
Fungicide (July 31)	None	Priaxor (4 oz./acre)	None	Priaxor (4 oz./acre	None	Priaxor (4 oz./acre
	ORGANIC SOYBEAN					
Soil texture/ drainage	Well- drained Honeoye silt loam					
Planting date	23-May					
Planting rate (seeds/acre)	150,000	200,000	150,000	150,000	200,000	150,000
Row Spacing	30-inch					
Variety						

	P92Y21 (no seed treatment)	P92Y21(organic seed treatment)	P92Y21(no seed treatment)	P92Y21(organic seed treatment)	P92Y21(no seed treatment)	P92Y21(organic seed treatment)
Tine weeding	June 12 (6 mph)					
Cultivate (3 times)	June 20, June 25, and July 6 (4 mph)					

Table 3. Costs of variable inputs, including seed, hopper seed treatments, (inoculant for conventional and Sabrex for organic), herbicide, and fungicide, in conventional and/or organic soybeans.

INPUT	**CONVENTIONAL**	**ORGANIC**
	$	
Seed/140,000	81.95 (including seed treatment)	50.95
Seed treatment	1.70/oz. (Cell-Tech inoculant)	7.04/oz. (Sabrex)
Herbicide	36.95/2.5 gallon (Glystar Plus)	-
Fungicide	550/gallon (Priaxor)	-

Table 4. Selected costs for conventional soybean under recommended management (S1) and high input management (S2), and organic soybean under recommended management (S3) and high input management (S4) at a Cornell Research Farm near Aurora, NY in 2015 [1].

	SOYBEAN TREATMENTS			
Selected Costs of Production[1]	**S1**	**S2**	**S3**	**S4**
	$ per acre			
Variable Inputs				
Fertilizers & Lime	-	-	-	-
Seeds	87.80	117.07	54.59	72.79
Sprays & Other Crop Inputs	12.51	31.38	3.95	13.29
Labor	0.44	0.88	8.88	8.88
Repairs & Maintenance				
Tractor	0.09	0.18	2.14	2.14
Equipment	0.34	0.69	3.05	3.05
Fuels & Lubricants	0.34	0.68	7.14	7.14
Interest on Operating Capital	2.54	3.77	1.99	2.68
Total Selected Variable Input Costs	104.07	154.65	81.73	109.96
Fixed Inputs				
Tractors	0.62	1.23	12.19	12.19
Equipment	1.63	3.27	12.65	12.65
Land charge	-	-	-	-
Value of management	-	-	-	-
Total Selected Fixed Input Costs	2.25	4.50	24.84	24.84
Total Selected Costs	106.32	159.15	106.57	134.79

[1]This reporting of costs focused on those costs that differed among the four soybean treatments. Fertilizer and lime costs, land charge, and value of management input did not differ among treatments, so items are blank. Seed costs differed among treatments due to price per unit differences between non-GMO and GMO seeds, and seeding rate differences for recommended vs. high management. Spray and other crop inputs that differed included pest and disease management materials, and hauling as a function of yield. Labor costs reported included only those attributed to sprays for treatments S1 and S2, and those attributed to weeding tasks for S3 and S4. Labor costs reported do not include labor associated with tillage, planting and harvesting tasks considered constant, not differing among treatments. Similar explanations underlie estimates for the remaining cost items that differ.

Table 5. Percent plant establishment, plant populations at the 10th leaf stage (V10), weed populations at the V12 stage, yield, stalk nitrate, and grain N content of corn in 2015 following three previous crops (2014) under conventional and organic cropping systems at recommended and high input management.

	PREVIOUS CROP		
TREATMENT	**CORN**	**SMALL GRAIN**	**SOYBEAN**
	% plant establishment (of seeding rate)		
CONVENTIONAL			
Recommended	100 a+	91 b	99 a
High Input	98 a	100 a	99 a
ORGANIC			
Recommended	84 c	84 c	86 b
High Input	93 b	89 b	97 a
	Corn populations-V10 stage (plants/acre)		
CONVENTIONAL			
Recommended	28,000 b	27,750 b	29,750 b
High Input	33,200 a	34,890 a	34,700 a
ORGANIC			
Recommended	24,400 c	25,460 c	24,950 c
High Input	30,375 ab	31,100 ab	32,875 a
	Weed densities-V12 stage (weeds/m^2)		
CONVENTIONAL			
Recommended	0.34 a	0.38 a	0.65 a
High Input	0.28 a	0.41 a	0.48 a
ORGANIC			
Recommended	1.65 b	2.40 c	3.10 bc
High Input	1.61 b	2.15 bc	2.52 c

	Yield (bushels/acre)		
CONVENTIONAL			
Recommended	158 b	175 a	156 a
High Input	172 a	170 a	161 a
ORGANIC			
Recommended	96 c	131 b	104 b
High Input	100 c	138 b	111 b
	Stalk Nitrate (ppm)		
CONVENTIONAL			
Recommended	427 a	501 a	420 a
High Input	378 a	382 a	361 a
ORGANIC			
Recommended	46 b	64 b	42 b
High Input	52 b	63 b	46 b
	Grain N (%)		
CONVENTIONAL			
Recommended	1.37 a	1.44 a	1.38 a
High Input	1.45 a	1.52 a	1.44 a
ORGANIC			
Recommended	1.16 b	1.25 b	1.15 b
High Input	1.19 b	1.20 b	1.16 b

$^{+}$Treatment means within the same column followed by the same letter are not significantly different according to Fisher's protected LSD at the 0.05 level.

Table 6. Days to emergence, percent plant establishment, plant populations at the 2nd node stage (V2), weed populations at the full pod stage (R4), and yield of soybean in 2015 following three previous crops (2014) under conventional and organic cropping systems at recommended and high input management.

	PREVIOUS CROP		
TREATMENT	**CORN**	**SMALL GRAIN**	**SOYBEAN**
	Days to emergence		
CONVENTIONAL			
Recommended	7.0 a+	7.0 a	6.75 a
High Input	7.0 a	7.0 a	6.75 a
ORGANIC			
Recommended	6.0 b	6.0 b	5.75 b
High Input	6.0 b	6.0 b	5.75 b
	% plant establishment (of seeding rate)		
CONVENTIONAL			
Recommended	84 b	80 b	80 b
High Input	92 ab	81 b	88 a
ORGANIC			
Recommended	96 a	86 a	92 a
High Input	87 b	80 b	88 a
	Soybean populations (plants/acre)		
CONVENTIONAL			
Recommended	125,850 d	119,205 c	120,530 c
High Input	183,120 a	162,405 a	176,460 a
ORGANIC			
Recommended	143,165 c	129,630 b	137,840 b
High Input	173,795 b	158,925 a	175,795 a
	Weed densities-R4 stage (weeds/m^2)		

CONVENTIONAL			
Recommended	0.1 a	0.3 bc	0.2 b
High Input	0.1 a	0.1 c	0.1 b
ORGANIC			
Recommended	0.3 a	0.9 a	0.6 a
High Input	0.2 a	0.5 b	0.5 a
	Yield (bushels/acre)		
CONVENTIONAL			
Recommended	40.7 a	49.8 b	43.6 a
High Input	44.7 a	55.7 a	45.5 a
ORGANIC			
Recommended	39.5 a	42.7 c	46.3 a
High Input	41.3 a	44.8 bc	46.9 a

+Treatment means within the same column followed by the same letter are not significantly different according to Fisher's protected LSD at the 0.05 level

Table 7. Revenue and estimated returns crop for conventional and organic soybean under recommended and high input management in 2015 following three previous 2014 crops.

	PREVIOUS CROP		
TREATMENT	**CORN**	**SMALL GRAIN**	**SOYBEAN**
	Revenue ($/acre)		
CONVENTIONAL			
Recommended	356.30 a+	435.84 a	381.15 a
High Input	391.21 a	487.38 b	398.04 a
ORGANIC			
Recommended	361.38 a	373.19 c	404.86 a
High Input	226.58 a	392.18 bc	410.11 a
	Estimated returns $/acre		
CONVENTIONAL			
Recommended	249.98 a	329.50 a	275.05 ab
High Input	232.06 a	328.25 a	238.89 b
ORGANIC			
Recommended	239.14 a	266.57 b	297.27 a
High Input	226.58 a	257.34 b	275.28 ab

+Treatment means within the same column followed by the same letter are not significantly different according to Fisher’s protected LSD at the 0.05 level